Martina Schäfer, Noara Kebir, Daniel Philipp (editors)

MICRO PERSPECTIVES FOR DECENTRALIZED ENERGY SUPPLY

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7th-8th of April 2011

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Foreword

When we started planning the conference "Micro Perspectives for Decentralized Energy Supply" at the beginning of 2010, we didn't know that future scenarios for global energy supply would be the dominating topic of spring 2011, spurred by the nuclear catastrophe in Japan. Climate change and limited fossil energy resources were reasons enough to discuss the "end of the fossil fuel era", which includes the accelerated provision of renewable energy capacities and efforts towards increasing energy efficiency. The catastrophe in Japan, however, sheds additional light on the vulnerability of centralized energy supply systems and high-risk technologies.
The international conference, taking place in Berlin in April 2011, focuses on questions of decentralized energy supply in Northern and Southern countries: issues which might gain greater relevance due to the current discussion and reorientation processes regarding questions of future energy supply.
The starting point for dealing with these questions at the Technische Universität Berlin (TUB) is the interdisciplinary postgraduate program "Microenergy Systems for Decentralized, Sustainable Energy Supply in Structurally Weak Areas", which has been funded since 2007. The idea for this program, which takes up questions beyond mainstream research agendas, originated amongst young postgraduates who were dedicated to providing solutions for those 1.4 billion people, mainly in Africa and Asia, who still today do not have access to clean and safe energy supply. The availability of modern energy services worldwide is regarded as being a necessary requirement for reaching the Millennium Development Goals of reducing world poverty by half by 2015 (UNDP 2005).
Meanwhile, forms of decentralized energy supply also have been playing an important role in Northern countries in the context of searching out alternatives for fossil and nuclear energy supplies. Solar, wind and biogas plants have experienced a boom in some European countries during the last two decades. With the expansion of the renewable energy sector, new questions have arisen concerning conflicting environmental goals (biodiversity versus reduction of CO2 emissions), land use conflicts (food versus biomass production) and acceptance by local populations.
The similarity of questions concerning the design and implementation of innovative technologies that serve users' needs while conserving the environment in both North and South has led to the initiation of the postgraduate program at TUB. The Hans Böckler Foundation has proved to be a partner that is strongly interested in the social and ecological aspects of decentralized energy supply.
Research activities in this area have quickly shown that much valuable experience exists all over the world. Innovative technical solutions as well as financing, implementation and regulation strategies are being tried out around the globe, but often practitioners and researchers dealing with these topics are unaware of each other. The response to the Call for Papers has confirmed the necessity for more intense exchange – there are many experiences that have been had and lessons learnt that others can benefit from! The international conference in Berlin wants to facilitate interaction between people who are dedicated to micro and meso solutions for renewable decentralized energy supply. It is expected to be a starting point for future research activities and intercultural as well as interdisciplinary dialogue.
We want to thank all institutions which have helped us in realizing this conference: First of all the Hans Böckler Foundation but also the Heidehof Foundation, the German Academic Exchange Service (DAAD) and the Innovation Center Energy at TUB.
We are looking forward to fruitful exchange regarding technical solutions that do not put humankind or the environment at risk, but rather contribute towards a more sustainable future.

The Editors: Martina Schäfer, Noara Kebir and Daniel Philipp

Micro-energy systems in low-income countries: learning to articulate the solar home system niche in Tanzania

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Abstract

Despite multiple efforts over two decades in Tanzania to apply a solar home system (SHS) diffusion „model" generated in Kenya, it is only in recent years that a Tanzanian SHS market has begun to grow. Why is it that the Kenyan „model" seemed to fail in Tanzania, even as the SHS market grew rapidly in Kenya; and why has the Tanzanian market grown rapidly since the early 2000s?

The objective of this paper is to explain the evolution of the Tanzanian SHS market. It applies the strategic niche management approach to the Tanzanian photovoltaic (PV) „niche" – the empirically identified set of actors, technologies and practices concerned with household electricity services using PV. By focusing primarily on the learning stimulated by a number of events, processes and projects, the research traces the dynamics of the socio-technical trajectory of the Tanzanian PV niche. This then enables reflection on the Kenyan SHS market and about the diffusion of sustainable energy technologies in poor developing countries more generally.

Keywords: Solar Home Systems; Kenya; Tanzania; Strategic Niche Management.

Introduction

The long-standing objective of rural electrification in developing countries is expected to deliver many benefits, including "improvements in health, education, and opportunities for entrepreneurship" (Dubash, 2002, p. 2). For decades, the assumption and practice has been to build centralised generating capacity and transmit the electricity over national grids (Goldemburg, Reddy, Smith & Williams, 2000, p. 375). However, despite years of effort, only a small percentage of the populations of many developing countries has access to electricity. More recently, interest has grown in the potential of photovoltaic (PV) technology to solve the problem of rural electrification. This interest is intensified because PV is aligned with sustainability objectives; and PV systems are modular. PV"s modularity is attractive for at least two reasons. One, it is more amenable to rural application where power needs are generally small – particularly in households – and grid infrastructure is weak or non-existent. Two, it is suitable for distribution through retail systems and so aligns with market-based approaches to development. Market-based development approaches – such as the Bottom of the Pyramid (BOP) (Prahalad & Hammond, 2002) – might provide „win-win" solutions: The poor gain greater access to services; private firms increase profits; and society achieves cheaper development than through public sector interventions.

A private market for household PV systems (solar home systems – SHSs) has grown in Kenya since about 1984; a market that is widely hailed as a success story among developing countries (Jacobson, 2004). Now, there is estimated to be more than 200,000 SHSs installed in Kenya, sold through the private market (Hankins, 2005). As a result, policymakers have been interested to use the Kenyan „model" to disseminate PV elsewhere in the developing world using the private sector (Hankins, 2007). Until recently, Tanzania had almost no SHS market despite interest from a number of actors, including some of those involved in enabling the growth of the Kenyan market. However, sales of PV began to grow in the early 2000s and the trend appears to be gaining pace, with an estimated 285 kWp[1] sold in 2007, having risen by 57% in one year (Felten, 2008). A number of large donor-supported projects have been recently active in the country, but there is also a burgeoning private sector of PV companies servicing a market that was estimated to be worth USD 2 million in 2007-2008 (Sawe, 2008).

What explains this recent rapid growth of the Tanzanian PV market, and does this success provide evidence that private sector led development is more effective than donor-funded interventions?

Research Objectives

Empirically, the objective is to explain the evolution of the Tanzanian SHS market, concentrating on particularly revealing aspects of this evolution. The theoretical objective is to offer an operationalisation of some of the key concepts in strategic niche management (see below), the conceptual framework used here. Flowing from these two objectives are policy-relevant questions on diffusing sustainable energy technologies in developing countries.

Theoretical Framework

Strategic niche management (SNM) is a conceptual framework that can be applied either analytically or normatively (Raven, 2005). Normatively, it is intended to be used for finding and developing sustainable solutions to societal functions, such as mobility or energy services. Analytically, it rests on the assumption that novel configurations of social practices and technological artefacts,[2] that together provide solutions to societal functions, emerge in protected spaces wherein

[1] kWp (kilowatt-peak) is equivalent to 1000 watt-peak. Peak watts refer to the maximum electrical power output for a PV module under standard test conditions (1000 W/m^2 solar irradiance at 25°C, air mass of 1.5 kg/m^3).

[2] The stream of literature that includes SNM analyses social and technical dimensions together, leading to the notion of *socio-technical* configurations. Social dimensions encompass cultural, social, economic and political aspects of the context within which technological artefacts are used.

experimentation proceeds free of constraints such as economic viability (Berkhout et al., 2010). Experimentation generates learning, builds networks of sympathetic actors, and begins to embed novel socio-technical configurations into the mainstream. SNM refers to such protected spaces as *niches*, while the mainstream consists of *regimes*. The broader context in which niches and regimes are situated is referred to as the *landscape*, and all three (niches, regimes and landscape) are connected in a hierarchical framework (see**Fehler! Verweisquelle konnte nicht gefunden werden.**) referred to as a multi-level perspective (MLP) (Geels, 2002). SNM is focused on evolution of the niche but is analytically open to interdependencies across the micro-, meso- and macro-levels of the MLP.

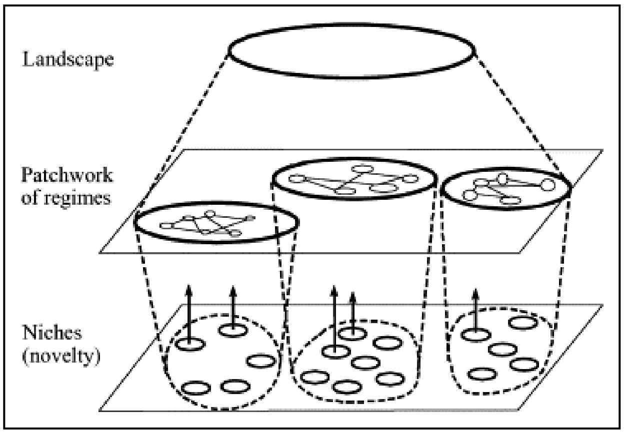

Figure 1: The multi-level perspective.
Source: Geels (2002, p. 1261)

When analysing the emergence of a novel socio-technical configuration from a niche, SNM directs us to investigate a number of interacting processes and their characteristics, as they relate to technological experiments in a social context. They can be summarised as follows (elaborated below): (1) the processes and quality of learning (see, e.g., Hoogma, Kemp, Schot & Truffer, 2002), (2) the composition and quality of social networks (see, e.g., Caniëls & Romijn, 2008; Raven, 2005; Romijn, Raven & de Visser, 2010), (3) the evolution of collective socio-technical expectations and visions (see, e.g., Berkhout, 2006; Geels & Raven, 2006; Raven, 2005), and (4) processes of institutionalisation (see, e.g., Deuten, Rip & Jelsma, 1997; Raven, 2005).

Learning

Learning is conceptualised in two forms within the SNM framework: first- and second-order learning. First-order learning arises when technological artefacts are tested in practical settings; it is an instrumental form of learning that is concerned only with the detailed functioning of artefacts, not with the underlying assumptions on which the use of such artefacts rest. In contrast, second-order learning arises "when conceptions about technology, user demands, and regulations are … questioned and explored" (Hoogma et al., 2002, p. 194).

Actor-Networks

Networks of actors are important for attracting resources to socio-technical experiments, building constituencies of support, and providing multiple sites for experiments from which varied lessons can be drawn and translated to other contexts (Raven, 2005). SNM posits that broad networks are more helpful for novel technologies than networks of regime insiders, who may be more interested in maintaining the status quo or only incremental innovations (Hoogma et al., 2002).

Expectations and Visions

Socio-technical expectations and visions are cognitive schemata that help to describe future states of the world in which particular socio-technical configurations perform societal functions better than current ones (Berkhout, 2006). When expectations and visions are shared widely among networks of actors they help to direct activity in particular directions – socio-technical trajectories (Geels & Raven, 2006). They also operate as recruiting devices, attracting actors and their resources to niches (Eames, McDowall, Hodson & Marvin, 2006).

Institutionalisation

Institutionalisation refers to the processes of embedding practices into the routines of actors – whether users or producers, policy makers and others – and the creation of policies, laws, regulations, and so forth (Deuten et al., 1997; Raven, 2005). SNM, therefore, understands institutions in the sociological sense of norms, conventions, practices, policies, laws and regulations; not as organisations (Hodgson, 2006).

Methods

It is straightforward to identify institutions and social networks in operation but perhaps less so for learning, and socio-technical expectations and visions. In this paper, these concepts are operationalised in a particular way. A fuller discussion that argues for this operationalisation can be found in Byrne (2009); here we simply state it.

Building on Berkhout (2006) and Eames et al. (2006), an expectation is a socio-technical „target" towards which actors align themselves and their activities, while a socio-technical vision specifies the means to achieve the expectation and defines the expectation in greater detail. We can see the operation of expectations and visions in, for example, arguments made for particular technologies, project goals, and „how-to" manuals.

We can relate learning to expectations and visions following Byrne (2009). First-order learning is generated when actors pursue a particular expectation: that is, they already hold a number of assumptions about a particular direction and then attempt to realise it, gradually filling in more detail to develop a vision. Second-order learning results in a change to those assumptions and a new direction to pursue; a new expectation, and the requirement for new first-order learning to envision it. Figure 2 shows these ideas. Actors initially work towards Expectation 1, making progress through first-order learning. At some point they may experience second-order learning that changes their assumptions about the expectation to realise, resulting in Expectation 2. This is then pursued through first-order learning once again.

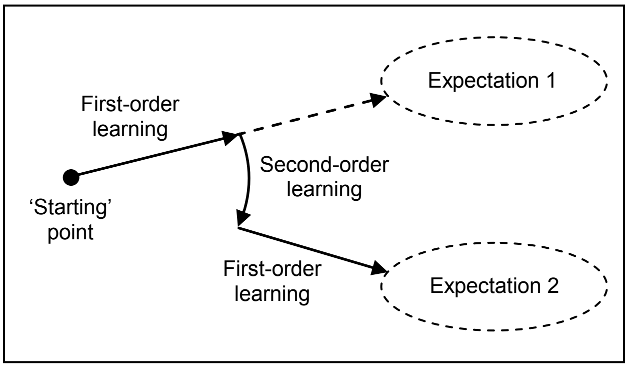

Figure 2: Schematic representation of first and second-order learning, and expectations and visions.
Source: Byrne (2009).

We can identify learning through changed behaviour and arguments, as well as changes and developments of knowledge communicated in reports and other documentation. First-order learning is recognised when there is activity that details a particular socio-technical direction or trajectory (see below). Second-order learning is recognised by a change in that trajectory.

Building on the notions of technological paradigm and trajectory in Dosi (1982), and the definition of a socio-technical regime (see, e.g., Hoogma et al., 2002, p. 19), we can develop a schematic representation of a socio-technical paradigm and trajectory. Dosi (1982, p. 152) defines a technological trajectory as a "pattern of „normal‟ problem solving activity … on the ground of a technological paradigm". His elaboration of a technological paradigm details the elements that make the "pattern" to which he refers, including (p. 153): relevant material technology; physical/chemical properties exploited; and technological and economic trade-offs. Hoogma et al. (2002, p. 19) define a socio-technical regime as:

> … the whole complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures.

Combining the definitions given in Dosi (1982) and Hoogma et al. (2002) we can describe explicitly the dimensions of a socio-technical paradigm. Assuming that a socio-technical niche can be conceptualised as a nascent regime, we can investigate the evolution of the various dimensions of a socio-technical paradigm – each particular pattern being a socio-technical trajectory – as niche actors attempt to establish a new regime. Figure 3 shows these ideas schematically. So, the direction of activity in each dimension combines to form a particular trajectory; a change in the direction on any dimension constitutes a change in trajectory.

Data Collection

The field research took place in Kenya and Tanzania between July 2007 and July 2008. Semi-structured interviews were conducted with a wide range of actors involved in PV activities in the two countries: governmental and non-governmental, the private sector, donors, and universities. Secondary sources included a wide range of documentary material: project proposals and reports, government documents, research and consultancy documents, and so forth. A number of respondents gave copies of reports and other documents that are difficult to find in the public domain.

Results

This section describes relevant aspects of the evolution of the Tanzanian SHS market. The description begins with an account of the arrival of PV in East Africa. We then review early activities in Kenya‟s SHS market, which had important influences on the activities pursued in Tanzania. Subsequent Tanzanian experiences are then described, focusing on those most revealing for developing our understanding of the evolution of this market.

PV Comes to East Africa

PV systems entered East Africa during the late 1970s to power telecommunications equipment (Duke, Jacobson & Kammen, 2002; Hankins & Bess, 1994; Mwihava & Towo, 1994). During the early 1980s, donors began to fund the installation of health-related PV systems, some in Kenya and Tanzania. The US Agency for International Development (USAID) funded clinic systems (Roberts & Ratajczak, 1989); and the World Health Organization (WHO) began a worldwide programme to immunise all children by 1990 (Henderson, 1989), including the installation of PV-powered vaccine refrigerators (McNelis, Derrick & Starr, 1988). Following these developments, a number of international companies set up offices or agents in Kenya (Abdulla, 2008; Energy Alternatives Africa [EAA], 1998; Hankins, 1990; Rioba, 2008) and Tanzania (Kimambo, 2008; Mbise, 2002; Sawe, 1989).

It is unclear whether the Kenyan and Tanzanian ministries responsible for energy were aware of these developments. Both countries had a ministry for energy by the early to mid 1980s, and their first energy policies reveal awareness of PV technology (Republic of Kenya [ROK], 1987; United Republic of Tanzania [URT], 1992). While both ministries were engaged in renewable energy projects, there is no evidence that they were active in the technology (Rioba, 2008; Sawe, 2008). For the most part, the ministries (and donors) were more concerned with finding solutions to the burgeoning problems around biomass energy.

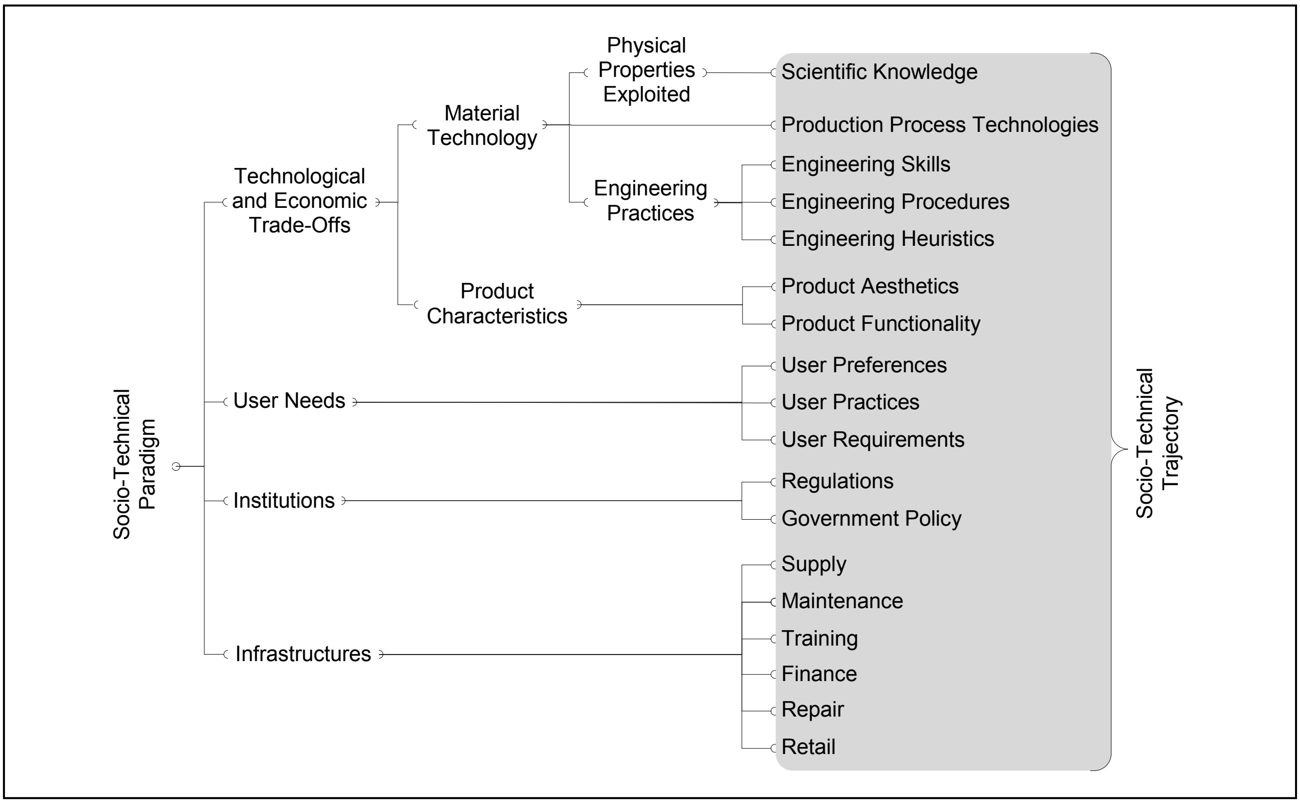

Figure 3: Dimensions of a socio-technical paradigm, with a particular configuration as a socio-technical trajectory. *Source*: Adapted from Byrne (2009) following Dosi (1982) and Hoogma et al. (2002).

So, in the early 1980s, there was no significant market in either Kenya or Tanzania for SHSs. Projects for commercial and community services systems continued and a market developed around these. Indeed, such projects still account for a large part of the installed capacity of PV systems in the region (Energy for Sustainable Development [ESD], 2003).

The Kenyan SHS Market Phenomenon

The Kenyan private market in SHSs is said to have started during 1984 and its beginning is attributed to the activities of Harold Burris, an ex-Peace Corps volunteer, after he set up the company *Solar Shamba* in a coffee growing region south of Mount Kenya (Acker and Kammen, 1996; Duke et al., 2002). Burris was an engineer who had worked in the nascent US solar industry (SolarNet, 2001) before coming to Kenya with the Peace Corps in 1977 (Perlin, 1999). During the middle of 1983 Burris met Mark Hankins by chance at a café in Nairobi (Hankins, 2007). Hankins was a Peace Corps volunteer teaching science at Karamugi Harambee Secondary School, which was in the process of considering electrification with a 5 kVA diesel generator[3] (Hankins, 1993). The generator was chosen because the cost of connecting to the grid would be about USD 21,000 (Perlin, 1999, p. 133). But, the Karamugi board of governors were persuaded to visit Burris" home PV system whereupon they were impressed enough to postpone purchase of the diesel generator and to trial the use of PV in four classrooms and the headmaster"s office (Hankins, 1993; Perlin, 1999). The systems were installed during the first to third quarters of 1984 (Hankins, 2007) and, according to Kimani and Hankins (1993, p. 93), the headmaster, some of the teachers and others in the community bought systems for their own homes "within six months of the school"s installation". This was a clear signal to both Burris and Hankins that there could be a market for SHSs[4]: Burris "saw that there was a lot of business and there was a coffee boom going on too so there was a lot of cash" (Hankins, 2007). A major factor in the demand for electricity was the desire to watch television. Portable DC TVs began to appear on the market in about 1981, and the TV signal became increasingly available during the 1980s (Jacobson, 2004).

In response to these developments, Burris moved to Embu where he renamed his business from *Kidogo Systems* to *Solar Shamba* (Jacobson, 2004) and began "to get heavily into the marketing" (Hankins, 2007), making use of an array of marketing approaches (Muchiri, 2008). Hankins, for his part, applied to Peace Corps for an independent placement in which he would work with Burris on a project to install PV systems in three more schools, and include in the package the training of local technicians (Hankins, 2007). According to Hankins, he and Burris believed the training element would be critical to the growth of the market in Kenya (Hankins, 1996, p. 6). By the third quarter of 1984, the Peace Corps had given approval for Hankins" independent placement, provided he work solely on the project with Burris

[3] kVA is kilovolt-ampere, a measure of electrical power.

[4] The term „solar home system" had not been coined at this time though (Hankins, 2007).

(Hankins, 2007). USAID funded 50% of the cost of the systems for the schools and the installations were done during 1985 and into 1986 (Hankins, 2007). Burris and Hankins developed manuals for the training aspect of the project, and the 12 trainees spent part of their time installing systems and part in classroom-based training. At the end of the project, the technicians were introduced to a number of the Nairobi PV suppliers who then employed some of them (Hankins, 1993) while others went on to work for Burris (Muchiri, 2008). An important outcome of the project was a „model" of PV dissemination that Hankins and others applied in both Kenya and Tanzania.

Burris continued to develop his business, and the Nairobi PV suppliers also became active in the SHS market, initially around Mount Kenya but later expanding across the country as others entered the market (EAA, 1998; Hankins, 1990, 1993; Rioba, 2008). The SHS market itself expanded quickly after 1986. In 1987 it is estimated that module sales were slightly less than 100 kWp but by 2001 annual sales had reached about 650 kWp (Jacobson, 2004). By the mid 1990s, the average system size was about 20 W and falling (van der Plas & Hankins, 1998). Using 20 W as an estimate of system size in 2001, 650 kWp represents about 32,000 modules. At the end of 2007, annual PV sales were estimated to be worth USD 6 million (Mutimba, 2007).

So, a private market for SHSs grew rapidly in Kenya from the mid 1980s and continues to be significant. It also appears that the work of Burris and Hankins had an important influence on its birth and growth. Furthermore, it appears that the private sector developed the market itself; an exemplar of market-based approaches to development. However, a closer examination of the processes by which the Kenyan SHS market evolved reveals that this private sector led reading is over simplistic. Private sector actors were indeed important in growing the market but contributions from non-market actors have been underplayed in the literature. This becomes clearer once we examine the evolution of the Tanzanian SHS market where the contributions of non-market actors are more visible. The next section describes some relevant aspects of this evolution, enabling us to analyse its lessons. In turn, this will help us to reflect on the evolution of the Kenyan SHS market.

The Tanzanian SHS Market Experience

This section reviews briefly the experiences with PV in Tanzania during the 1980s and the influence of the Kenyan dissemination model from the 1990s. It then reports the activities of a number of PV projects and shows how these helped to develop the Tanzanian PV niche. This account then lays the ground for an SNM analysis in the subsequent section.

PV in Tanzania during the 1980s

As mentioned earlier, PV was introduced to Tanzania to power telecommunications equipment and was certainly in operation by the beginning of the 1980s (Mwihava & Towo, 1994). There had been an earlier interest in the technology, when the possibility of its use in villages was considered at a workshop in Dar es Salaam in 1977 (UTAFITI, 1978). Little immediate action came of these early discussions, at least in terms of governmental activities. MWE (the energy ministry) developed some interest in PV but was never able to secure resources to implement projects (Sawe, 2008). In any case, the more pressing concern was the issue of wood supply for household energy-use (Nkonoki, 1983). However, the use of PV expanded into other applications such as lighting for remote railway stations, community-scale water pumping, and health-related systems such as vaccine refrigerators (Sawe, 1989).

The few PV companies present in Dar es Salaam during the 1980s tended to service this project market, the exception being BP which had sold about 150 "domestic systems" in the period 1989 to 1994 (Mwihava & Towo, 1994, pp. 73-76). Outside Dar es Salaam there were very few active in PV. Tropical Solar Systems (TROSS) was started in Arusha by Stephen Kitutu in 1983 or 1984 (Arkesteijn, 2000), although Kitutu found there was more demand for solar water heaters than PV (Kitutu, 2008); and Karagwe Development Association (KARADEA), located in a remote part of north western Tanzania, received and installed a donation of about 20 PV systems from Swedish Church Aid in 1987 (Kasaizi, 2008; Musa, 2008). There may have been other donated systems in the country but there is little documentary evidence. In short, there were only scattered and fragmented PV activities in Tanzania up to the late 1980s.

Transferring a Model from Kenya

A significant event in the development of the PV sector in Tanzania was a workshop held in Nairobi and Meru in 1992. Burris and Hankins initiated the workshop, helped by the Kenya Energy and Environment Organisation (KENGO), with funding from the African Development Foundation (ADF) (Hankins, 2007; Kimani, 1992). It brought together participants from 10 African countries and elsewhere for an intensive period during which they received practical PV training. Six attendees were from Tanzania; from both the private and public sectors, as well as NGOs and university. For Hankins, two project opportunities in Tanzania arose from the workshop. One was with an NGO near Arusha and the other with Oswald Kasaizi"s organization KARADEA, mentioned earlier.

By the end of 1992, Kasaizi and Hankins had written a proposal for an ambitious project based around the idea of a Solar Enterprise Centre, encompassing a set of interlinked activities: a solar business; training courses; development of affordable small systems; installation of demonstration business PV systems; and a credit scheme (Kasaizi & Hankins, 1992). The Swedish development organisation Sida funded the construction of the building that contained a classroom and store, while the Commonwealth Science Council (CSC) funded the first training course in November 1993 (Kasaizi, 2008; de Groot, 1997). But not everything in the proposal was funded and so the project became focused more on training, with the result that the Solar Enterprise Centre became the KARADEA Solar Training Facility (KSTF).

Hankins, who had started the company Energy Alternatives Africa (EAA), led the training at KSTF. The form of the course was the same as that he and Burris had developed for the USAID-supported schools project in Kenya and the 1992 Nairobi workshop (Jackson, 2008): there was classroom-based theory and practical work installing systems. KSTF continued to run courses once or twice per year up until about 2004 (KSTF, 2009). While the course content and form evolved over time, it continued to be the model that Hankins (and, later, many others) used in the ensuing years in Tanzania and other parts of eastern Africa. Indeed, a number of the participants went on to become influential in PV projects in Tanzania and elsewhere, helping to replicate the model (Byrne, 2009). Hankins himself, through EAA and with other organisations, conducted at least two similar courses in different locations in Tanzania: In April 1996, at the Simanjiro Animal Health Learning Centre (about three hours south of Arusha); and, in October 1997, at Wasso Hospital, near to the Serengeti. As with the previous courses, the trainees had classroom-based sessions and practical work (EAA-ApproTEC, 1998; Hankins, 1998). But, unlike in Kenya where there was entrepreneurial activity by the participants once they had finished the course, there was little business impact in Tanzania (Hankins, 2007). When the Tanzanian trainees returned home, they had no resources to implement projects, there were no local PV suppliers, and there was little awareness of PV and so no noticeable demand (Jackson, 2008).

Nevertheless, we can identify other outcomes. KSTF trained about 175 technicians (KSTF, 2009), while many others were trained in replica courses elsewhere. Some went on to influential positions in the PV sector that later developed. For example, Mzumbe Musa (KSTF"s first Tanzanian manager) (Jackson, 2008; Musa, 2008), later coordinated the UNDP-GEF PV project in Mwanza (more below). Finias Magessa, who worked for TaTEDO (more below), was trained at KSTF and later became the Executive Secretary of the Tanzania Solar Energy Association (now the Tanzania Renewable Energy Association) (Magessa, 2008). Gaspar Makale, who had been with KARADEA from the 1980s (Kasaizi, 2008), later trained many others in the East Africa region. And KSTF did other pioneering work locally. For instance, there were attempts to use micro-finance to increase the sales of PV systems (Burris, Katumi & Hankins, 1992; Kasaizi, 2008); and bringing together participants from distant parts of the East Africa region helped to form networks of actors who would later collaborate. Furthermore, KSTF attempted to commercialise their activities around the Kagera region: They installed systems for aid agencies in the Rwandan refugee camps and hospitals; sold solar lanterns; attempted to open battery charging stations in villages; and tried to source the equipment within Tanzania, with a view to developing the local supply chain (Jackson 2008).

TaTEDO's PV Activities

The Tanzania Traditional Energy Development and Environment Organisation (TaTEDO), a local NGO which had been created in 1992 to help build indigenous capacity in the energy sector, began activities in PV around 1996 (Magessa, 2008; Sawe, 2008). These started with a small PV system installed at their offices by Burris who had started a PV company in Dar es Salaam (Ultimate Energy), having left a job with a GEF PV project in Zimbabwe sometime in 1993 (Kolowah, 2008; Magessa, 2008). Following a major rural energy study funded by Sida (Hifab-TaTEDO, 1998), TaTEDO secured funding from Hivos and Norad to undertake a large PV project that included networking, training, awareness-raising, demonstration systems, and market development (Arkesteijn, 2000). The project ran from 1999 to 2002, covering Dar es Salaam, Mwanza, and Kilimanjaro Regions (Sanga, 2008); selected because of their poor grid infrastructure, potential for renewable energy use, and strength of the local cash economy (Arkesteijn, 2000). The project began with internal capacity building, including Finias Magessa"s training at KSTF (Magessa, 2008). TaTEDO then invited Makale from KSTF, Burris and me[5] to design a training course to be delivered in the three project regions, beginning with Dar es Salaam in May 2000. The format of the course was similar to KSTF"s PV training. At the end of this first course there was a stakeholder"s workshop in which the Tanzania Solar Energy Association (TASEA) was created (Arkesteijn, 2000). TaTEDO conducted two more courses the same year, one in each of the other two regions. After each course, there was a stakeholder"s workshop and those attending were invited to join TASEA. Although the hope had been that the trainees would include PV activities in their organisations, very few were able to do so (Sanga, 2008). Only those who were already involved in PV prior to the course – mostly from PV retailers – continued after the training. Consequently, TaTEDO targeted those working in PV companies, or who demonstrated promising entrepreneurial energies, for the second round of training courses (Sanga, 2008). This was a more successful approach and was continued in a second project that ran until 2005, concentrating on building technical and entrepreneurial capacities.

Umeme Jua and Market Development

An important relationship developed between TaTEDO and the Dutch PV manufacturer Free Energy Europe (FEE) in the late 1990s after FEE sent a Dutch engineer – Marcel van der Maal – to work with them while introducing FEE"s amorphous modules to the Tanzanian market (van der Vleuten, 2008). Frank van der Vleuten (Marketing Manager of FEE) wanted to sell into Tanzania, having already experienced success with FEE modules in Kenya. In 2000, Karlijn Arkesteijn, a Dutch masters student, joined van der Maal at TaTEDO and conducted the first PV actor survey in Tanzania (Arkesteijn, 2000). This analysed the extent to which PV actors were networked with each other, and sought their views on what needed to be done to develop the market. Apart from the network in Dar es Salaam, Arkesteijn found that most PV actors in Tanzania were working in isolation – the networks were weak and fragmented. Nevertheless, the views on what was needed to develop the market were highly convergent. An overwhelming response was the need for a central actor who could

[5] I had been working in a small PV project in northern Tanzania and delivered part of the training on KSTF"s policymakers course, where I met Magessa.

coordinate information and knowledge exchange. Beyond this, all the issues identified in the 1998 rural energy study were mentioned: lack of awareness of PV; difficulty sourcing equipment; lack of standards; taxes too high; not enough training; no finance, and so on (Arkesteijn, 2000).

Other market surveys followed. EAA, together with TaTEDO and Ameco (a Dutch consultancy), conducted market assessments in 2001-2002 in five regions. In 2004, TaTEDO and Fredka International (a Tanzanian consultancy) conducted a baseline survey of the PV market in Mwanza Region (TaTEDO-Fredka, 2005). Then in 2007, another set of regional market surveys was undertaken for Sida and the Ministry of Energy and Minerals (MEM) (Sida-MEM, 2007; 2008). They all converged on similar conclusions to the Arkesteijn and 1998 studies, and characterised the market in similar terms, although each contributed new information as well. For example, the EAA surveys revealed two unexpected market segments (van der Vleuten, 2008). One was for charging mobile phones and the other was a "migrant worker" market: People with steady incomes working away from their home area who sent goods home. PV was potentially attractive to them and they became a source of reliable business, in contrast to farmers who only had seasonal incomes (van der Linden, 2008). Arkesteijn‟s study helped to prepare the way for FEE‟s subsequent entry into the Tanzanian market (van der Vleuten, 2008). This became *Umeme Jua* – a joint venture with TaTEDO and Fredka International. By 2002, Umeme Jua was officially registered and Jeroen van der Linden became its first managing director.

Umeme Jua had intended to apply the model of supply that FEE had successfully used in Kenya. That made use of the dealer network of a large player (Chloride Exide in Kenya). However, no such player existed in Tanzania and so Umeme Jua identified dealers individually in the regions in which it decided to operate, hence the market surveys (van der Linden, 2008; van der Vleuten, 2008). This was a slow process that is unlikely to have occurred if Umeme Jua had not had significant funding from the Dutch government (Arkesteijn, 2009). But, over time, they built a network of retail dealers around the country and complemented this with a network of technicians who could service the local demand (van der Linden, 2008; van der Vleuten, 2008). Part of the reason this was a slow process is that it required training of the dealers and technicians. Initially, Umeme Jua used the Kenyan training model. However, Umeme Jua began to realise that this was unsuitable for most retailers and developed a course that could be conducted in repeated visits to a shop, and delivered in a few hours each time (van der Linden, 2008). This required extensive travel, and so was burdensome, but it generated other benefits. One of these was the building of trust between Umeme Jua and the retailers by cultivating long-term relationships (Arkesteijn, 2009). There were also incentives for dealers to sell more modules, including better terms depending on the quantities sold, supported by guaranteed delivery (van der Vleuten, 2008).

Other marketing techniques included demonstrating systems in public locations around the country and advertising on local radio stations (Arkesteijn, 2009). And Umeme Jua made extensive use of marketing provided through the Free Energy Foundation, also funded by the Dutch government. This was available to all PV actors in Tanzania, together with the use of the „free brand‟ *Solar Sasa* (Schuurhuizen, 2008). Arkesteijn[6] introduced standard systems that reduced the need for long explanations to customers in shops, as well as simplifying design and supply requirements. And Umeme Jua experimented with financing of SHSs. A number of these attempts failed but hire purchase was very successful (van der Linden, 2008). By 2008, Umeme Jua turned over about USD 1 million of business, which was estimated to be about 50% of the Tanzanian PV market (Sawe, 2008).

Subsequent PV Projects

Four other large PV projects followed the Umeme Jua enterprise, although some of them were initiated earlier. Each of them bears remarkable similarities to the Umeme Jua approach and this is an indicator of the extent to which the PV actor-networks in Tanzania became far more integrated than they had been when Arkesteijn conducted her survey in 2000. Initiated in 1999, a UNEP-GEF funded project to develop dissemination networks across eastern Africa finally got underway in 2005 (de Villers, 2007). In 2002, the project held a stakeholder‟s workshop and Jeroen van der Linden was present (UNEP-EAA-MEM, 2002). It is unclear whether this was significant but it does establish that there was at least a connection between the Umeme Jua team and the UNEP-GEF project manager EAA (which later became Energy for Sustainable Development Africa [ESDA]). The UNEP-GEF project certainly appears to have been influenced by Hankins‟ understanding of the success factors in Kenya: Target a cash-crop area, set up a dealer network, train technicians, and raise awareness. Whether there was any influence on Umeme Jua, or vice versa, is difficult to judge. But much the same approach used was repeated in a subsequent Sida-MEM project (see below), which was also managed by EAA/ESDA.

In 2004, the GEF funded another project but this time through the UNDP and in Mwanza Region (URT-UNDP-GEF, 2004). It also suffered a long delay before implementation but this afforded Umeme Jua an opportunity to influence its final design (van der Linden, 2008). It concentrated on the Mwanza Region for the first three to four years, and was to be replicated in other lake-zone regions (Musa, 2008). While it had been influenced by the Umeme Jua approach, it was not identical. It donated some systems, which were placed in strategic locations as demonstrations, and experimented with productive uses of PV: Powering barber shops, providing mobile phone charging services, and others. Furthermore, it included a policy dimension, which involved the development of PV standards in collaboration with both the Tanzania and Kenya Bureaus of Standards. It also experimented unsuccessfully with micro-finance (Musa, 2008). Nevertheless, the project was successful and the PV market expanded significantly in Mwanza Region.

In 2005, a Sida-funded project got underway, known as the Sida-MEM project. Like the UNEP-GEF and UNDP-

[6] Arkesteijn was Umeme Jua‟s second managing director.

GEF projects, it suffered a long delay before implementation (Kårhammar, 2008). Its final design was based on consultations between the incoming project manager, Jeff Felten, and local PV actors (Felten, 2008). So, once again, there was interaction and influence among those implementing projects in Tanzania – between Umeme Jua, UNDP-GEF and UNEP-GEF. Still, it was not identical to the other projects. It did share the multi-dimensional market development approach in general, and included a policy aspect similar to the UNDP-GEF intervention, as well as network building and marketing in line with the other projects. The difference was in the duration of its interventions. It targeted three regions initially but then moved on to other areas quickly. The approach was to identify potential dealers, train them, conduct local marketing campaigns, and then continue supporting the dealers with training for some time afterward. The network element of the project was achieved by providing funds to TASEA, which paid for a website, annual solar days in Dar es Salaam, and a sector magazine – SunENERGY. It appears that the project was successful. Indeed, it surpassed its own targets in the first two years of operation. According to Felten‟s figures as of 2008, the market grew by 57% between 2006 and 2007 to an estimated 285 kWp. If the average size of a system were 20 Wp (as we used in the Kenyan case) this would amount to about 14,000 modules. The price per watt-peak of PV fell from USD 12.07 in 2006 to USD 9.85 in 2007.

An SNM Analysis of PV Market Development

The Kenya Socio-Technical Vision

The evidence suggests that, prior to the Karamugi installation, Burris had not considered PV systems for households as a viable business opportunity. This was despite his using PV for his own home and his attempts to develop a business with Kidogo Systems. And Hankins was not experimenting at all with PV. However, the experience of the Karamugi installation and subsequent adoption of household systems generated powerful second-order learning for both Burris and Hankins. The new expectation they now held was then partially envisioned through the USAID-funded schools project. This expectation/vision was then shared first with the trainees and then with the Nairobi PV suppliers. The success of the Kenyan market over the next few years served to strengthen the hold of this vision, and to help collectivise it amongst other actors. By the time Hankins and Kasaizi prepared the KSTF proposal, the vision had become highly detailed, reflecting the first-order learning gained in the Kenyan market.

From this we can understand the logic of the socio-technical vision held by Hankins and others. When the opportunity arose to work on PV market development in Tanzania, it would have seemed perfectly sensible to apply the same logic in order to realise the same vision. Hence, we can talk of a Kenyan model of PV market development and understand Hankins‟ actions in Tanzania as applying that model. But, as the narrative of the Tanzanian experience describes, the market did not develop as anticipated. We now analyse the Tanzanian experience with the intention to explain why this model did not work in Tanzania.

The Tanzania Socio-Technical Vision

We should acknowledge here that the model applied in Tanzania at KSTF was not the one that Kasaizi and Hankins had initially envisaged. Their hope was to implement a multiple set of activities but they were unable to secure funding for these. Consequently, the model actually applied was much simplified. This shows the importance of Berkhout‟s (2006) observation that expectations and visions must be collective if they are to be socially significant. While Kasaizi and Hankins shared a common vision for market development through KSTF, they did not succeed in collectivizing this amongst the donors. As a result, they were unable to recruit the resources necessary to realise *their* vision. Furthermore, the model actually applied was adopted by those actors who followed the KSTF training and so the vision that the KSTF „model‟ articulated became the one collectivised.

Implicit in that vision were various assumptions that had not been tested in the Kenyan experience. One, the vision assumed that spatial geography was not important. Two, it neglected the significance of descriptive and connective articulation. Three, it assumed that a functioning business culture existed. Four, it did not take account of risk. We can examine these in turn and compare the Kenyan and Tanzanian activities to reveal how, once these assumptions were tested in Tanzania, and actions adjusted accordingly, the market began to respond. This analysis also reveals some important lessons for our understanding of the evolution of the Kenyan market.

KSTF was located in a remote part of Tanzania, on the opposite side of the country to the Dar es Salaam suppliers. The nearest source of PV equipment was Kampala. Even Nairobi was closer than Dar es Salaam. Getting equipment to KSTF was a serious undertaking that could use many days, particularly if equipment was not in stock when the technician arrived at the supplier‟s door. Many of the trainees went back to similarly rural locations after their training. Setting up a business in such circumstances would have been extremely difficult. There was no secure supply chain so getting equipment would require collecting the cash for a system and then travelling by bus to Dar es Salaam (or Kampala or Nairobi) to buy it. If the supplier had no stock then the technician would have to stay in the city searching for alternatives. Once the equipment was bought it would have to be transported by bus again back to the site for installation. One would have to possess enormous entrepreneurial energy and hold very deeply an expectation of PV business to undertake such an endeavour.

In contrast, the Karamugi and three-schools projects were implemented in a relatively densely populated and wealthy part of Kenya a few hours from the Nairobi suppliers. This proximity facilitated more reliable supply of equipment and lower costs for travelling between the city and the centre of the PV market. Moreover, market information could flow more easily, particularly as a number of technicians – who already knew each other from the three-schools training – were working in the same area travelling to sites to install systems.

While KSTF was able to further the processes of descriptive and connective articulation of the PV niche, it was the entry of TaTEDO that accelerated the processes through a large and relatively integrated project. An important element in this was the formation of TASEA. This grew rapidly by recruiting course participants and so helped to collectivise a PV expectation more widely. However, the first round of training courses exposed a gap in TaTEDO"s understanding and vision. The networks it was building did not include many from the private sector. Private sector actors proved crucial to the articulation of the niche because they were able to make use of the training once they returned to their work, unlike many who were in NGOs. This continuation of activity was important to be able to realise the essential first-order learning needed to refine expectations into coherent visions. It also helped to begin the process of connective articulation of both the supply and demand sides of the market. That is, retailers could connect to customers and articulate for them an expectation or vision of PV – raising demand – and connect to the supply because they needed equipment to sell.

In Kenya, the activities of Burris had begun much of this articulation work. He already knew the suppliers in Nairobi and his marketing activities, together with the demonstrations of the school projects, were able to connect to the demand side. Then, as systems were installed in homes, they acted as demonstrations themselves and the owners articulated expectations and visions of PV for their friends.

We can see the importance of this in Tanzania following the activities of Umeme Jua. A large part of that effort was focused on connecting the demand and supply sides of the market, as well as connecting together the supply chain. In Umeme Jua"s case, connecting the supply chain meant some years of work identifying retailers and learning to understand their needs. One consequence of this understanding was dramatically shorter training offered *in situ*. An important detail in the PV market development vision of Umeme Jua was to establish retailers physically close to customers, underlying the spatial geography point discussed above. The final part of connecting both demand and supply was to raise demand. That is, to articulate for customers a PV vision through advertising and demonstrations. This took huge effort and significant finance, which hints at the issue of the other two assumptions I am arguing were not tested in Kenya: a functioning business culture and the neglect of risk.

A number of the interviewees in the field commented on the issue of trust in business in Tanzania, or lack of it. Of course, this is an issue in all countries but it was particularly acute in the minds of those I interviewed. This may be because the institutional environment is weak in Tanzania, because the country is still learning how to function as a market economy following its African socialist experiment, or perhaps a combination of both. Whatever the reason, significant efforts had to be made to build relationships with private sector actors. Umeme Jua noticed the benefits of this (Arkesteijn, 2009), as did Musa (2008) in the UNDP-GEF project. The Kenyan experience with a market economy is much longer and a business culture is embedded more deeply. The issue of trust may loom large there also, but private sector actors are more ready to do business as quickly as possible.

Finally, we come to the issue of risk. This relates, of course, to business culture and, less obviously perhaps, to articulation. But it also plays a role in the importance of spatial geography. Indeed, it appears to be fundamental and is mitigated by better articulation.

For example, we have seen that Tanzanian technicians returning home after their training could not be expected to start a PV business given the lack of discernible demand. Expressed differently, poor articulation of demand presented them with a high-risk endeavour. As market demand was demonstrated – better articulated – so risk was lowered and more actors were attracted into the market. We can see this even with Burris, who was using PV to power his home. It was not until demand for SHSs was articulated for him following the school installations that he began to develop and market household systems. Likewise, the Nairobi suppliers did not pursue the household market until the demand was demonstrated to them by Burris" activities; until demand was clearly articulated. Umeme Jua was able to develop its market-building activities because a significant part of the financial risk was absorbed by the Dutch government grant. The advent of the other large projects in Tanzania served to lower risk even further, demonstrating across many parts of the country that demand for SHSs existed and detailing it increasingly clearly for others to see. The lowering of risk was also important from the customer"s perspective. The school projects demonstrated – articulated – a PV vision for them. Home installations did the same for many others. And, the demonstrations of systems in public spaces did the same in Tanzania.

Reflections on the Kenyan Market

The analysis here raises questions about the usual understanding of the Kenyan PV market phenomenon. This is often portrayed as private sector led development. However, a closer examination shows that the private sector was not alone in developing the market. Donors played an important, if not always deliberate, role as well. The USAID-supported schools project, for example, helped to accelerate Burris" market development activities by enabling him to train sales technicians at no cost to himself. They were then able to multiply his efforts to scout for business. Some of the same technicians were later employed by the Nairobi suppliers bringing with them their knowledge of Burris" activities and short-cutting some of the learning necessary to enter the PV market. This also lowered the risks for the Nairobi suppliers by articulating the existence of a demand for SHSs. Once they had adopted this new expectation they were then attracted to the market where they pursued largely first-order learning to refine how to service that market. There was no space here to report fully the developments in Kenya after the three-schools project but they would also reveal that further donor-supported interventions helped to foster second-order learning that the private sector would have been unable bear the risk to create. In general, a closer examination of the Kenyan PV niche reveals that, once a new expectation was created in this way, the private sector tended to adopt it and refine it – envision it – through first-order learning. The Kenyan SHS market developed as the result of both private and public sector activities, as did the Tanzanian market.

General Conclusions

One of the general conclusions to emerge from this discussion is that a socio-technical analysis reveals clearly the extent to which functioning markets are complex systems. It is unsurprising that markets are complex but, when they are functioning in some sense „efficiently", we cannot readily see in what ways and to what extent this is so. By applying SNM, we were able to examine the extent to which PV market development in East Africa was a private sector endeavour. By using the notion of socio-technical trajectories, we were guided to examine many more dimensions of market structure and functions. Moreover, because we were looking for changes in these trajectories, we were guided to the sites of learning. We operationalised these concepts by linking expectations and visions with first and second-order learning. This helped to reveal the extent to which work had to be done to develop the markets in both countries and, especially in our case, the niches in both countries.

The Kenyan PV market „phenomenon" has long been used to exemplify private sector led development. Donor influence has usually been downplayed, based on a lack of direct sales impact. But, donor support was important for other reasons. If it had been missing, it is highly likely that much of the second-order learning that led to new products and business models (in both Kenya and Tanzania) would not have occurred. The most obvious reason for this is risk-aversion on the part of the private sector; entirely understandable given the conditions of the Kenyan and Tanzanian markets and the often precarious income sources of customers. However, even where donor support did not enable new products or business models, it did enable the enhancement of niche networks. The private sector, for its part, often then did the first-order learning to develop coherent visions once new expectations had been formed; an important aspect of niche development and market growth.

In contrast to the sometimes trite characterisation of the Kenyan PV market as private sector led, the Tanzanian PV market could be seen as a purely donor led development, given the number of donor-funded projects in place at the same time. Once again, however, this is a simplistic reading of the situation. Indeed, the recent Tanzanian PV market story is actually rather complex. Donors were certainly involved in various ways for a long time but no significant market developed. Part of the explanation for this, of course, was the poor economic conditions. Nevertheless, there did not appear to be a significant market developing when the large TaTEDO project was underway at the end of the 1990s. Yet, within a couple of years, the market began to grow quickly. It was a private actor who finally began to find some measure of success there. But, a significant proportion of that actor"s resources to develop the market came from a donor. And the other donors who are currently involved are not supplying equipment or subsidising directly; private actors are selling the technology.

So, in both cases, we see that the participation of donors and private sector actors was important. The balance of involvement may have been different between the two niches, and the kinds of interventions were certainly different: the Kenyan niche saw a number of experiments with products, while the Tanzanian niche is getting help with business and technical training. But the point is that it is difficult to see that either niche would have developed without the participation of both donors and private actors. The role of donors appears to have been, for the most part, to mitigate risk and so enable experimentation that led to second-order learning. The role of private actors appears then to have been mainly about adopting the expectations formed from experiments and developing the details of these – envisioning them – through practice. But, above all, whether the reality was as neat as this, there was considerable work done to develop the niches and markets. This is especially clear in the case of Tanzania, which only recently began to change from a „socialist" to market economy. However, the Kenyan niche displayed similarities in terms of risk-aversion.

A number of important implications arise from the recognition that the market-based diffusion of PV in East Africa – especially Tanzania – has taken a major effort to establish, if indeed it is established. Clearly, market structures in Tanzania are not well developed and it takes time and resources to achieve their development. Many donor-supported projects have been active in Tanzania for just one technology, and mostly concurrently. Moreover, the „model" of PV diffusion in Kenya had to be adapted to Tanzania. One clear policy-relevant conclusion that flows from these observations is that we need to foster context-specific learning that attends to a broad set of dimensions, not just technical improvements and lower prices (important though these are). And, the analysis here suggests that the private sector in poor developing countries cannot bear the risks associated with the experiments necessary to create this broad learning. This suggests an important role for donors and the public sector more generally. Projects, funded by public and private sources, can provide the sites for context-specific learning if they are understood to be socio-technical experiments rather than solutions in their own right.

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